Province of
British Columbia

Ministry of
Environment
Skeena Region

ALLUVIAL FAN STUDY

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PROJECT:	ALLUVIAL FAN STUDY
LOCATION:	SMITHERS, BRITISH COLUMBIA
CLIENT:	BRITISH COLUMBIA MINISTRY OF ENVIRONMENT SKEENA REGION

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APPENDICES

DRAWINGS

1. INTRODUCTION

1.1 Purpose and Scope

This report provides the results of a study of flooding and debris torrent hazards on an alluvial fan near Kathlyn Lake, north of Smithers British Columbia. The study was carried out for the Water Management Branch of the Ministry of Environment, Skeena Region.

The study area includes three watercourses: Simpson, Biggs, and McKinnon creeks.

The purpose of the study was to develop a Fan Management Plan for the management and safe development of the fan. This plan comprises hazard zone identification, recommendations for development guidelines for each zone, and alternative mitigation measures.

The scope of this study includes:

- determining the extent of flood hazards and avulsions;
- determining the potential for debris torrents;
- identifying hazard zones for the existing conditions;
- identifying any works required to ensure that a zone does not change to a higher hazard class in future due to foreseeable development or stream activity;
- preparing conceptual designs of alternative mitigation measures for reducing hazards;
- identifying hazard zones for the fan with mitigation measures constructed; and
- identifying recommendations on the application of Section 734 of the Municipal Act.

The hazard zones are shown on the maps included with this report.

1.2 Procedure

This study was carried out in five phases: collection and interpretation of existing data; site inspection; data reduction and analysis; identification of mitigation measures; and reporting.

The collection and analysis of existing data included:

- obtaining and interpreting historical aerial photographs;
- compiling suitable base maps;
- collecting streamflow data; and
- preparation of a study base map.

This phase began immediately after authorization and continued throughout the study.

The field work involved surveying profiles and identifying the morphology of the lower reaches of the creeks. The Water Management Branch and local residents provided historical information on flooding and alterations to the creeks.

Data reduction and analysis included assembling the collected information into readily usable form. Physical characteristics of the creeks were summarized, hydraulic and sediment transport parameters were identified, and existing hazard zones were delineated on the base map.

Identification of mitigation measures included:

- development of conceptual design alternatives;
- comparing alternatives;
- defining development constraints for the fan; and
- delineating hazard zones with mitigation measures in place.

2. SITE DESCRIPTION

2.1 Physiography and Geology

The site comprises an area of 3 km^2 with three creeks which flow from Hudson Bay Mountain (El. 2600 m) of the Bulkley Ranges to the Bulkley Valley. The study area is bounded to the west by the CNR track, and to the north and south by the extent of influence of Biggs and McKinnon creeks, respectively. The key plan is shown on Drawing A-1001.

Physiographically, the site is along the Bulkley Valley at the base of the Bulkley Ranges of the Hazelton Mountains. The terrain slopes gently towards the south end of Kathlyn Lake.

Simpson, Biggs, and McKinnon creeks originate at high elevations on the southeast slopes of Hudson Bay Mountain. Bedrock outcrops are along the channel sides throughout the steep upper reaches of the creeks. Biggs and Simpson Creeks originate above the tree line, and avalanche tracks extend well below the tree line. Small debris lobes are visible on air photos. Simpson Creek originates in a high, wide (probably glacially formed) valley which is mantled by talus slopes and some landslide debris. The exit from the valley and the channel of Simpson Creek are undersized in comparison to the headwater valley.

The steep mountain slopes abruptly change to the more extensive and gently sloping terrain of the Bulkley Valley. At this abrupt change in relief, successive layers of sediment have been spread over the land by braided creek tributaries which have rapidly lost their transport capacity due to reduced gradient and seepage into the permeable surficial materials. The surficial materials are rocks, gravels, and sands.

The alluvial fan was probably produced by glaciofluvial action towards the close of the Pleistocene era as glaciers receded from the Bulkley Valley and into the mountains. The Bulkley Valley was formed by a series of glaciers that cut a trench between the Hazelton and Skeena Mountains. Towards the end of the Pleistocene era the Bulkley River cut into the glacial till of the trench as the glaciers receded into the mountains. The receding glaciers continued to carve mountain channels and glacial meltwater conveyed bedload which was deposited at the gradient change from the steep mountain slopes to the gentle gradient of the valley. A series of alluvial fans coalesced to form a gently sloping plain at the break in topography between the Bulkley Ranges and the Bulkley Valley. This series of coalesced fans is referred to as a piedmont.

Fluvial deposits have contributed to the fan since the last glacial period. Today, erosion and aggradation on the fan create hazards for the residents. Channels on alluvial fans are prone to lateral migration and sudden relocations (avulsions).

Profiles of the lower reaches of Simpson, Biggs and McKinnon Creeks are shown in Figures 1, 2 and 3, respectively.

2.2 Climate

A meterological station is located at Smithers Airport, some 3 km away from the study area. Data from this station provides excellent information on the climate at low elevation; however, there is a climate gradient up the mountain slope towards the origins of the creeks. Precipitation generally decreases downslope, and a larger proportion falls as rain.

The area is in the interior climatic zone; precipitation is low and a significant proportion falls as snow, and temperatures vary seasonally and diurnally. At the airport the mean annual precipitation is 522 mm, 331 mm of rainfall and 191 mm water equivalent of snowfall. Spring is the driest

FIGURE 1

SIMPSON CREEK PROFILE

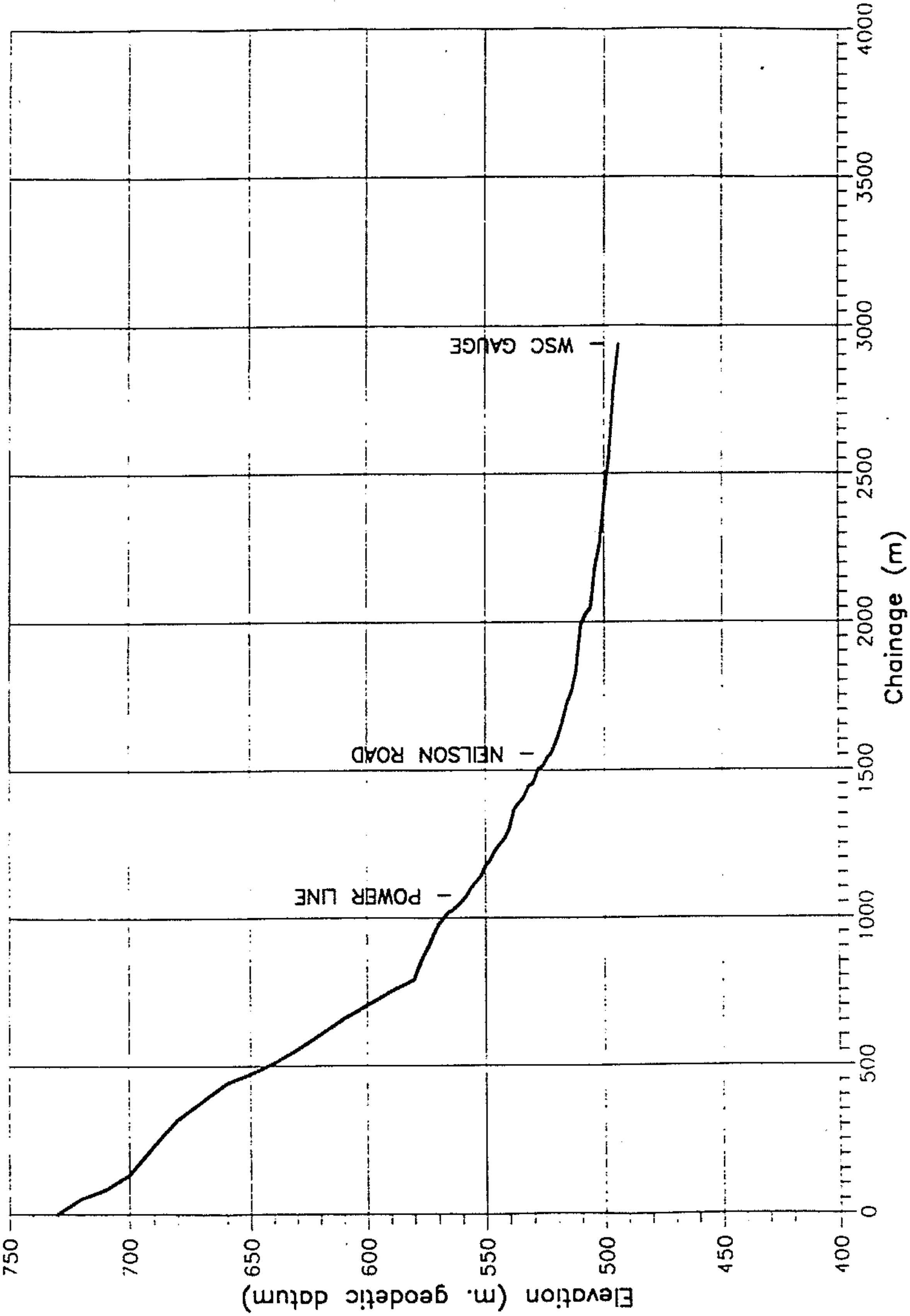


FIGURE 2

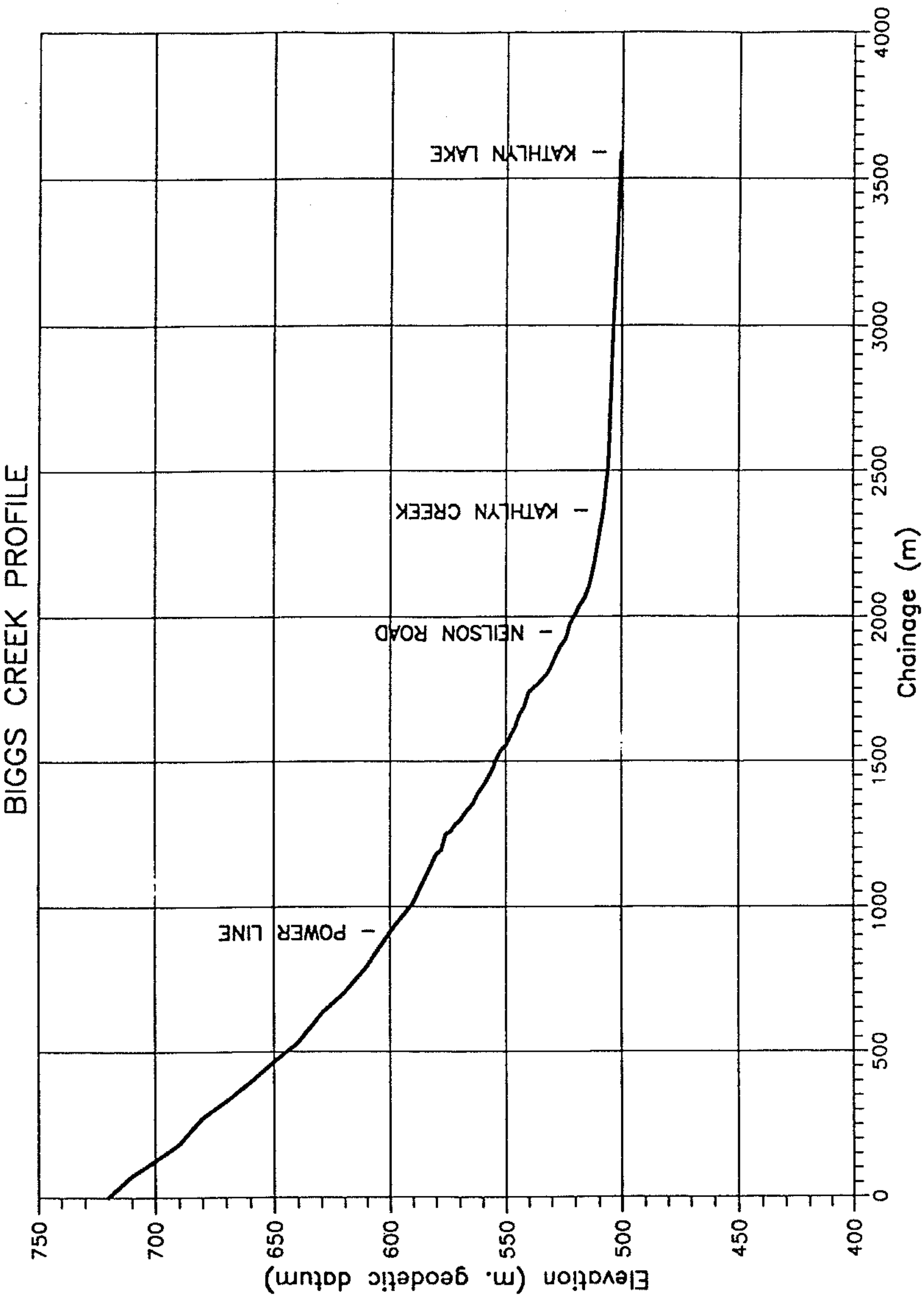
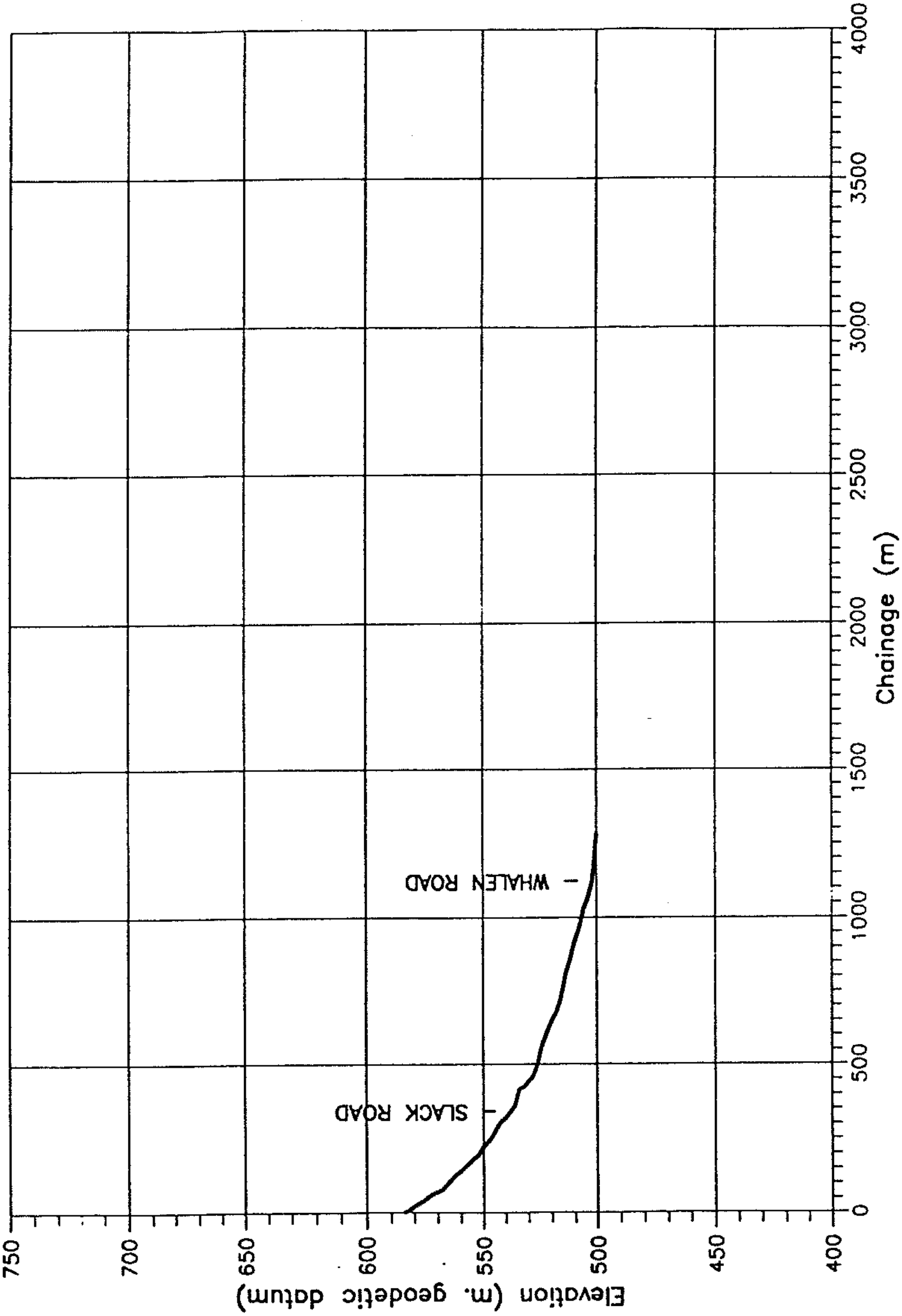

BIGGS CREEK PROFILE
KATHLYN LAKE
KATHLYN CREEK
NEILSON ROAD
POWER LINE
Chainage (m)
0
500
1000
1500
2000
2500
3000
3500
4000
Elevation (m. geodetic datum)
750
700
650
600
550
500
450
400

FIGURE 3

McKINNON CREEK PROFILE



season and summer and autumn are relatively wet. Average temperatures generally remain below freezing from November to March.

Snow courses have been maintained on Hudson Bay Mountain at elevation 1480 m since 1972, and at elevation 1520 m from 1965 to 1977. These locations provide information on snowmelt from the upper reaches of the creek catchments. The mean difference in the water equivalence of snow between May 1 and June 15 is 347 mm at the active snow course and 445 mm at the inactive one.

2.3 Hydrology

Complete annual streamflow records are available for Simpson Creek at the mouth since 1975 and four years of partial records are also available. The Water Survey of Canada gauge is some 1400 m downstream from Nielsen Road. A significant amount of seepage from the fan enters Simpson Creek between Nielsen Road and the gauge; nevertheless, the gauge record provides excellent data on the runoff regime for the area.

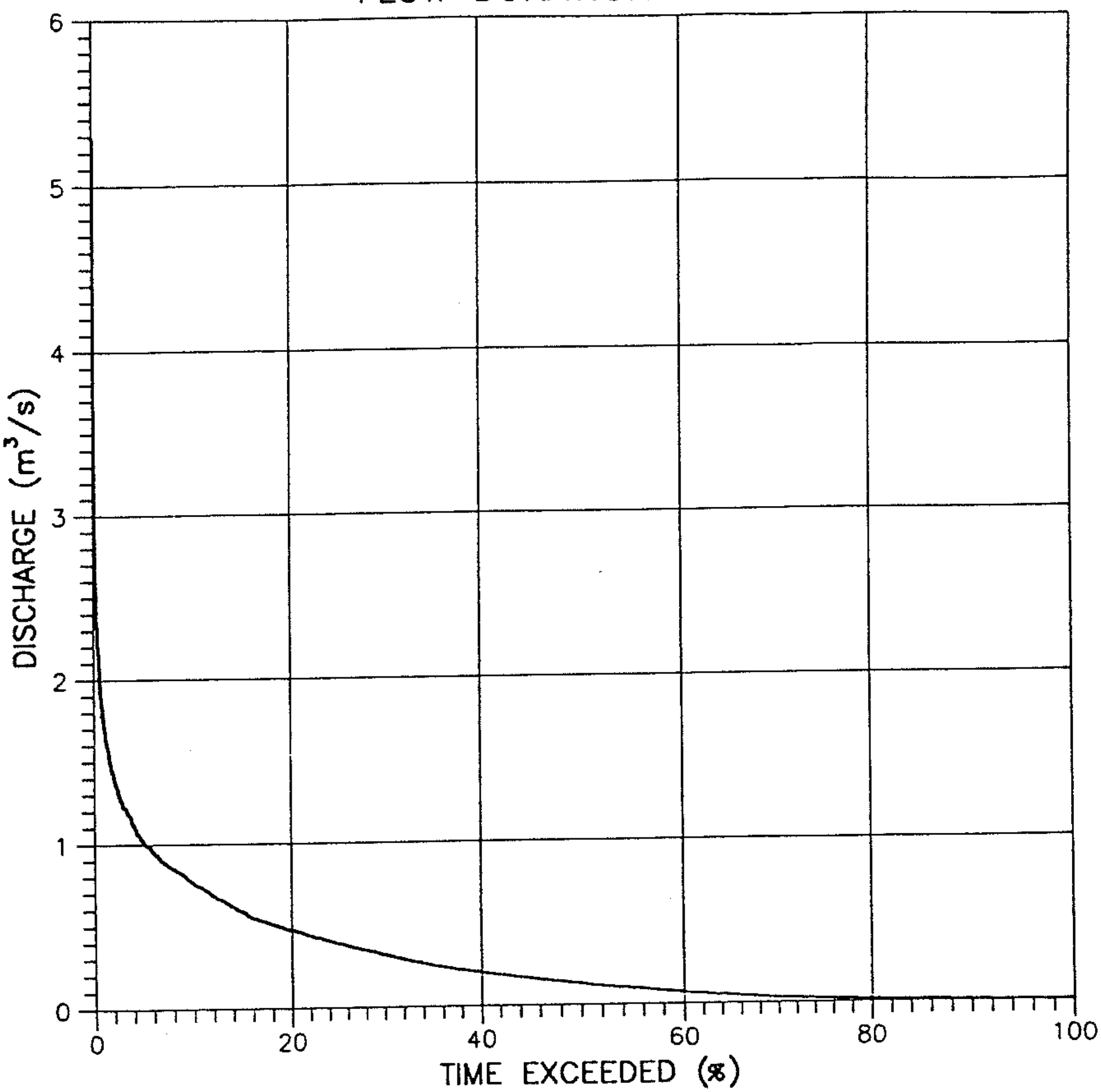
Simpson Creek has a 13.2 km^2 drainage area up to the gauge; at Nielsen Road the drainage area is 11 km^2. The drainage area of Biggs Creek at Nielsen Road was estimated to be 4 km^2, and the drainage area of McKinnon Creek up to Slack Road was estimated to be 2.5 km^2.

Mean annual runoff in Simpson Creek amounts to 8170×10^3 m^3 or 619 mm distributed evenly over the watershed. The runoff varied from 514 mm in 1980 to 886 mm in 1976.

Seasonal variation of Simpson Creek streamflow is illustrated in Figure 4. Flow varies widely by season and by the hour; seasonal variation is caused by the seasonal distribution of rainfall and snowmelt, hourly variation is a result of the quick reaction time of the small steep drainage basins to changes in weather.

FIGURE 4

SIMPSON CREEK AT THE MOUTH
FLOW DURATION CURVE



Daily discharges for the period of record were used to plot the flow duration curve for Simpson Creek at the mouth, Figure 5. The discharge is greater than 1 m^3/s 5% of the time, or about 18 days per annum on average. The discharge exceeds 2 m^3/s less than 1% of the time, or about 3.5 days per annum on average. High flows occur for only short durations; however, the instantaneous discharge peaks can be 100 times greater than low discharges.

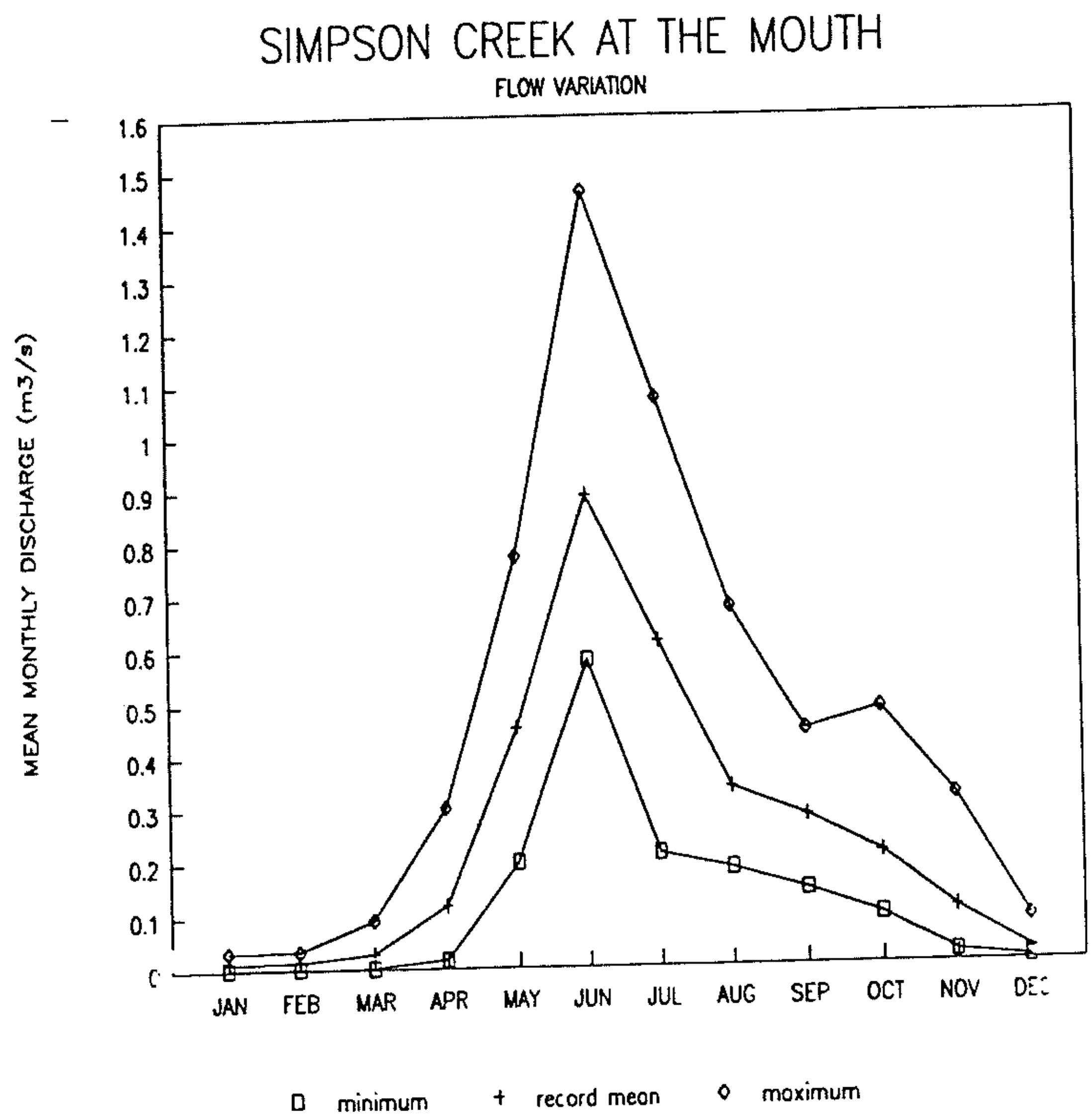
Annual peak discharge events usually occur in spring or autumn, but sometimes in summer. Spring and autumn events occur due to melting of the snowpack on Hudson Bay Mountain in combination with rainfall events. A prolonged winter and sudden warming that suddenly melts the seasonal snowpack in combination with rainfall can produce very high runoff; this happened in June 1986 to produce the extreme flow recorded at the gauge. Early snowfall in the mountains can melt quickly under warm autumn rains, thus causing high creek flows. High summer runoff is caused by intense local convectional storms.

2.4 Development

Most of the development occurred in the 1970s and 1980s in established 5-acre parcels. At present there are some 40 houses and a few small farms along Slack, Nielsen, Whalen, and Aspen roads. The area is administered by the Nechako-Bulkley Regional District. Drawing A-002 is the cadastral map of the study area.

Roads cross each of the three creeks; culverts convey Simpson and Biggs creeks under Nielsen Road, and a small bridge on Slack Road crosses McKinnon Creek.

FIGURE 5


SIMPSON CREEK AT THE MOUTH
FLOW VARIATION
MEAN MONTHLY DISCHARGE (m3/s)
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
minimum
record mean
maximum

3. BACKGROUND

3.1 Flooding

A series of flooding and erosion problems have occurred over the years mainly due to the inherent instability of creeks crossing alluvial fans. The instability of the creeks was increased by removal of vegetation upon development, and the situation has been further aggravated by incomplete attempts to stabilize the channels. Unauthorized channelization, channel relocation, and bank vegetation removal along Simpson Creek were recorded in 1978.

Over the past 10 years the Water Management Branch has assisted in alleviating flooding problems that are caused by aggradation and channel outbreaks. Remedial work has been done annually in various locations to channelize and to train channels away from residences. In some cases, the remedial efforts have been identified by residents as the cause of their problems.

The Ministry of Transport and Highways is responsible for the road crossings of the creeks. The first culverts installed were found to be inadequate due to blockage by bedload deposits during heavy runoff. Subsequently, larger culverts have been installed at Simpson and Biggs creeks and a bridge has been placed over McKinnon Creek.

In 1983 high flows in Simpson Creek caused extensive bank erosion downstream of Nielsen Road which could have resulted in an avulsion. Larger riprap was placed by the Ministry of Transport and Highways.

Flooding occurred along the three creeks during a storm event of September 27, 1988. Some residences along Slack Road were inundated by overflow from McKinnon Creek when the culvert was blocked with bedload deposits. Flooding near Biggs Creek was also caused by bedload blockage of a culvert; Nielsen Road was inundated and four driveways were eroded. Several residences were inundated by a breakout from

Simpson Creek upstream of the powerline right-of-way and bank protection was eroded from the right bank downstream of Nielsen Road.

Subsequent to the 1988 flooding, a bridge was placed on Slack Road to cross McKinnon Creek, a larger culvert was installed under Nielsen Road at Biggs Creek, channelization was done on all three creeks, and riprap was placed along Simpson Creek at Lot 1 of Plan 8739 and Lot A of Plan 8665.

The Water Management Branch channelized Simpson Creek for some 150 m downstream from Nielsen Road in autumn 1989 to alleviate the aggradation problems. Aggradation and the possibility of a breakout of Simpson Creek continues to be a problem during annual periods of high flow, particularly between Lot 1 of Plan 8739 and Lot A of Plan 8665.

Two residents have a disagreement on the "correct" alignment of Biggs Creek downstream from Nielsen Road. The creek generally remains in a road right-of-way between two lots; however, at high flows it inundates a small area of Lot 3 Plan 8422, on the south side of Biggs Creek. The resident wants to reduce the risk of flooding by diverting the creek to a previous channel but the neighbour argues that this would prevent his plans for enhancing fish habitat. Also, the resident on the north side of the creek wants to ensure that the creek does not deviate from his water intake which is about 100 m downstream from Nielsen Road. The residents have a difference in agreement which has likely been aggravated by recent minor changes in the course of Biggs Creek. The lateral shifting of the creek likely results from transport of bedload through a 1.6 m culvert installed in 1988. Bedload has accumulated to the crest of the smaller, older culvert; this crest is almost the same elevation as the invert of the newer culvert. The inlet area appears to have been a deposition pit until the new culvert was installed.

McKinnon Creek has not caused flooding since the Slack Road bridge was constructed and channelization completed. However, the owner of Lot 2 of Plan 5234 is concerned about deposition on his land downstream from the channelized reach which has apparently widened the floodplain.

4. HYDROLOGIC ANALYSIS

A hydrologic analysis was carried out to estimate the extreme flows on Simpson, Biggs, and McKinnon creeks in the vicinity of past problem areas and conceptual mitigation structures. The extreme flow estimates were design parameters for the mitigation alternatives.

Annual maximum daily discharge data from Simpson Creek at the Mouth, Water Survey of Canada (WSC) Station 08EE012, are available for 20 years. A site flood frequency analysis was carried out using the WSC program, CFA88. The Log Pearson III distribution was used to estimate extreme flows at the gauge.

No other WSC station in the Nechako-Bulkley hydrologic zone has a small catchment area and a long period of record; therefore, a regional flood frequency analysis was not carried out.

An extreme mean daily flow equation with parameters for small catchments around Smithers was developed by Mr. Arthur Beaumont, P.Eng., retired design and survey engineer formerly with the Ministry of Transport and Highways, Prince George. Mr. Beaumont (personal communication) stated that the parameters were calculated from observations of small creeks over a 15- to 20-year period. The observations included catchment areas, high water marks, and estimated catchment storage. Flow estimates by this equation were found to corroborate estimates from site frequency analysis on the Simpson Creek data. As a result, the "Beaumont Equation" was used to estimate extreme mean daily flows on Biggs and McKinnon creeks. Information on the Beaumont Equation is provided in Appendix III.

Based on a comparison of peak instantaneous and daily records for Simpson Creek, an instantaneous to daily ratio of 2.0 was used for all creeks.

Table 1 lists the results of the flow estimates for Simpson, Biggs, and McKinnon creeks.

TABLE 1

Creek Name	Flow Estimates (m^3/s)							
	Mean Daily				Instantaneous			
	200-year	100-year	50-year	10-year	200-year	100-year	50-year	10-year
Simpson	7.8	6.6	5.6	3.7	15.6	13.2	11.2	7.4
Biggs	3.3	2.8	2.3	1.5	6.6	5.6	4.6	3.0
McKinnon	2.3	1.9	1.6	1.0	4.6	3.8	3.2	2.0

5. BEDLOAD ANALYSIS

Mitigation measures include either removal of the bedload from the creek upstream from the usual areas of aggradation, or conveying bedload beyond the usual area of aggradation. For both of these concepts an estimate of bedload quantities is necessary.

Evidence proves that the three creeks have high bedloads at high discharge: large volumes of deposited material have been removed from the channels, breakout channels have developed where the creek bed has aggraded above the elevation of the adjacent land, and bedload has been heard rolling through culverts. The bedload size distribution varies with discharge, cross section, and gradient. Most bedload was estimated to be from 50 mm to 400 mm effective diameter.

Bedload was estimated according to the methodology presented by Smart and Jaeggi. Their methodology is based on tests on slopes ranging from 3% to 20% and was found to provide better estimates than the Meyer-Peter/Müller equation. The method uses a Shields entrainment function that is corrected for steep slopes. The slopes of the alluvial fan vary from 2% to 6%.

Two key parameters for bedload estimation are gradient and discharge. Creek gradients were surveyed and flows were estimated by hydrologic analysis.

Extreme event and mean annual bedload volumes were calculated. Extreme event mean daily flow events over a one-day duration were used to estimate extreme event bedloads. The flow duration curve for Simpson Creek at the streamflow gauge was pro-rated by drainage area to estimate the time of exceedance of the minimum flow for bedload movement. The results of the analysis are listed in Table 2.

The analysis and evidence show that the creeks transport large volumes of bedload at infrequent high discharges. Actual bedload may vary significantly from the estimates.

TABLE 2

Creek	Estimated Bedload Volume (m^3)				
	200-year Event	100-year Event	50-year Event	10-year Event	Mean Annual Total
Simpson	2600	2000	1500	800	900
Biggs	1000	700	550	300	400
McKinnon	600	450	350	200	200

6. HYDRAULIC ANALYSIS

6.1 Creek Crossings

There are three main creek crossings in the study area: two under Nielsen Road to convey Simpson and Biggs creeks and a Slack Road bridge crossing of McKinnon Creek. The capacities of these crossings were estimated and the results are summarized in Table 3.

The culverts and bridge may plug with deposited material before the hydraulic capacity is exceeded. The culvert inlet area on Biggs Creek traps bedload because of the wide cross section area. Occasional removal of deposits would prevent partial blockage of the new culvert.

TABLE 3

Creek	Crossing Type	Size (mm)	Return Period of Instantaneous Flow Capacity
Simpson	Arch Culvert	2590 x 1880	10 year
Biggs	Circ. Culvert	1600	50 year
McKinnon	Bridge	approx. 2100 x 1400	100 year

7. HAZARDS

7.1 Flood and Avulsion Hazards

All creeks on the fan present a hazard due to the channel instability and flow variability. Alluvial creek instability can be dichotomized into lateral migration and avulsions. Simpson Creek provides good examples of these instabilities: the shape of Simpson Creek fan is evidence that the lower reach of Simpson Creek has migrated northward, and in 1988, a temporary avulsion occurred due to a debris jam.

A significant quantity of debris, such as talus and trees, is available on the apex of the fans. Debris can accumulate and cause an extreme flow to break out of its channel. Biggs and McKinnon creeks have well-defined channels near their apexes; therefore, do not present extreme avulsion hazards in those reaches. In contrast, Simpson Creek is not well defined in some locations near the apex so the hazard of an avulsion in this reach is relatively high. The location of an avulsion cannot be predicted with certainty; however, it is most probable that flow from an avulsion would be partially conveyed in one of the old channels across the fan. If an avulsion occurs, it would be at high discharge, and a large area could be inundated.

Avulsions on the lower slopes of the fan could be caused locally or as an extension of an upstream avulsion. An avulsion originating on a gentle slope would probably be caused by unstable banks rather than a debris blockage. Unstable banks are common on the lower slopes of the fan, but no locations of immediate danger to development were identified during the site visit.

7.2 Debris Flow Hazards

Biggs Creek and the drainage between Biggs and Simpson creeks do not present a debris flow hazard on the alluvial fan. A small amount of debris on the steep bedrock upper slopes, small fans, and a lack of evidence of debris flow deposits led to this conclusion. Avalanche hazard on the upper slopes is not expected to be a concern on the lower slopes.

Simpson Creek originates in a high elevation, oversized valley with steep side slopes that contribute a significant quantity of talus and landslide debris. A source for debris flows in Simpson Creek is therefore available. Triggering mechanisms would include a landslide dam within this valley, with the resulting pond saturating and mobilizing a debris flow, or large precipitation or snowmelt events mobilizing debris deposits which have grown to a metastable size within the valley. Although such an event may be plausible, evidence of recent debris flow events on the fan was not detected. The probability of such an event is therefore considered low. Should such an event occur, the significant result is expected to be filling of channels with debris at slopes of about 6°, followed by avulsions and downstream flooding.

7.3 Hazard Mapping

The hazard zones shown on the hazard maps are approximate boundaries of the site specific hazard resulting from floods, avulsions, or debris flows. The path of flood water could be directed by local features such as embankments or ditches. Exact paths are thus unpredictable and the hazard boundaries shown are not exact.

Drawing No. D-1003 identifies the hazard areas on an orthophoto base.
Drawing No. D-1004 shows the hazard zones on a cadastral map base.
The following is a description of the hazard zones:

Extreme hazard zone

- debris torrent impact possible; and/or
- erosion or avulsion is probable.

High hazard zone

- high probability of flooding; and/or
- avulsions are possible.

Moderate hazard zone

- moderate probability of flooding; and/or
- avulsions may occur but are unlikely

Low hazard zone

- low probability of flooding; and/or
- avulsions unlikely

8. MITIGATION MEASURES

8.1 General

Alluvial fan occupancy should be compatible with the risk involved and the degree of protection that can be provided. Neither complete flood control and stabilization nor abandoning the entire alluvial fan is a feasible solution. During exceptionally severe events creeks will overflow land and roads. The design of any development should recognize this fact and make sure that peak flows can be accommodated with minimum damage.

Aggradation and bank erosion are characteristics of the creeks which have led to most of the avulsion and flooding problems. Mitigation measures must focus on limiting aggradation and controlling erosion.

The conventional solutions of realignment and channelization have been followed in the past. Channelized creeks permit high velocities which increase the potential for bank erosion and deposition of sediment further downstream. The extent of channelization to date has probably had only a minor impact relative to the natural instability; however, continued channelization could induce new problems downstream.

Alternative mitigation measures investigated include limited channelization, rehabilitation, and preservation. Channelization is useful for conveying very high discharges and bedloads, but the man-made channels can cause visual blight in the countryside and maintenance is expensive. Rehabilitated or preserved channels provide natural beauty and wildlife habitat, but the risk of possible inability to convey exceptionally large floods must be accepted by the residents.

Creek rehabilitation and preservation is an inexpensive method of stabilization. Rehabilitation provides a condition of equilibrium by preserving natural morphological characteristics and streambank activity. Preservation of natural characteristics is particularly well suited for areas which are not yet developed. Development plans for these areas should include tree preservation and planting, stabilization of the natural creek geometry, and setback dykes to provide accommodation of estimated peak flows.

Surface water intake relocation and local channelization have been carried out in some locations due to local migration of creeks. This has aggravated some residents and disturbed the creeks, but groundwater usage would easily eliminate these problems. Groundwater is likely to be available at shallow depths and may be better quality than surface water. Residents should be encouraged to install wells for water supply.

Mitigation measures for the existing flood problems and for reducing the flood hazards of potential development areas are discussed for each creek in Sections 8.2, 8.3, and 8.4.

Cost estimate details are presented in Appendix I and Drawing D-1005 shows the alternatives.

8.2 Simpson Creek

8.2.1 Mitigation of Existing Problems

The right bank of Simpson creek is not well defined in some reaches. These areas are susceptible to avulsion and should be properly identified and protected with large rock to restrain high discharges. The avulsion-prone area extends to the apex of the fan, about 600 m upstream of Nielsen Road. This reach should be inspected and low bank areas identified for placement of fill and channelbank riprap. Extreme care should be taken to avoid damage to bank vegetation. The estimated cost of limited protection is $20,000.

Prevention of avulsions should be carried out in conjunction with reduction of channel aggradation as discussed below.

Significant reduction of existing flooding problems on Simpson Creek can be achieved by forcing bedload deposition at a location where it will not induce flooding by creek aggradation. Once most of the bedload supply is removed, the downstream channel will attain a new condition of equilibrium and stabilization of the channel becomes an easier task. Alternative concepts are:

<u>Alternative 1. Chute</u>
A 160 m long chute from the downstream end of the culvert on Nielsen Road would convey the bedload of the creek to the relatively flat gradient area on Lot 1 of Plan 8739. The chute design has a smaller cross section area than the existing creek; therefore, the flow velocity would be higher than in the present creek. Bedload would be transported in the high velocity chute to a deposition area at the outlet. The chute would be constructed at the existing gradient.

The chute could either be constructed with concrete or with a semi-circular corrugated steel culvert. A concrete chute would be 2.5 m wide by 1.6 m deep, a steel chute would have a 3.05 m diameter.

A discharge apron at the downstream end constructed with layers of large riprap would protect the outlet of the chute. Riprap could be salvaged from bank protection work on the outlet side of the culvert. Periodic inspection for scour would be required.

Bedload would deposit at the end of the chute and periodic removal of sediment would prevent sediment from backing up the chute and increasing the flow depth upstream.

Land may have to be purchased or leased to provide a bedload accumulation area and access for removal.

The cost estimate, excluding land purchase, is $101,000 for a concrete chute and $65,000 for a metal chute. The cost of annual average deposition removal was estimated to be $9,000.

Advantages of a chute are:

- easy access for removal of material; and
- stabilized channel for length of chute.

Disadvantages of a chute are:

- may not be aesthetically acceptable;
- vertical wall may be unsafe;
- land may have to be purchased to provide access and deposition area at chute outlet; and
- abrasion of the chute by bedload.
- potential loss of fish habitat

Alternative 2. Deposition Zone

A deposition zone on Crown Land upstream from Nielsen Road would remove most of the bedload before it can deposit downstream.

A deposition zone is a flow deceleration reach which reduces velocities sufficiently to cause deposition of bedload. The velocity is decreased by introducing an excavated pit with containment berms along the course of the creek. The pit could be located either immediately upstream of Nielsen Road, where access is easy, or on a relatively gentle slope halfway between the road and powerline right of way. An excavation to contain the estimated 50-year event plus the annual average bedload volume would be approximately 100 m long, 30 m wide and 1 m deep at the downstream end.

The excavation should provide an adequate supply of large rocks for construction of an erosion resistant sloping channel.

The outlet would be a boulder and rock structure with a 1.0 m rise to the existing downstream creek invert. Low flows would percolate through the outlet structure, and high flows would be forced over it. Large material from the excavation could be used to construct the outlet.

The deposition zone would help protect residences downstream; therefore, a capacity equal to the annual average bedload plus bedload from a 50 year runoff event is recommended, a total 2400 m^3.

Periodic removal of deposits would maintain the capacity requirements. The structure would require inspection for scour.

A deposition zone immediately upstream of Nielsen Road was estimated to cost $84,000. Further upstream on the relatively gentle slope above El. 538 m, the estimated cost is $53,000. Annual removal of deposition was estimated to cost $9,000.

Advantages of a deposition zone are:

- may increase infiltration, hence slightly reduce peak discharge; and
- upslope deposition zone would not be visible from developed area.

Disadvantages of a deposition zone are:

- creek downstream of deposition area would change to a new condition of equilibrium, i.e. scour would probably increase slightly for at least one runoff season (note: this could be an advantage if the downstream channel is deepened);
- vegetation must be cleared for excavation; and
- removal of deposits would require periodic access in forested area by heavy equipment.
- potential barrier to fish passage

Alternative 3. Widened Channel

Widening of the creek downstream of the culvert would increase the area available for deposition without inundating land. The channel would be centred on the existing channel and be widened by 4 m on both sides for 100 m length. The banks would be sloped at 2H:1V and large excavated material would be used for protection. Aggradation in this reach could cause a local breakout without leaving the excavated channel. Periodic removal of deposits would be required to maintain the bedload deposit capacity of the channel.

Land may have to be purchased for widening of Simpson Creek along a 100 m length.

The cost estimate for widening the channel, excluding land purchase, is $51,000. Removal of deposition would cost an estimated $9,000 on average per annum.

Advantages of a widened channel are:

- easy access for removal of material;
- very large discharge capacity.; and
- minimum fisheries impact.

Disadvantages of a widened channel are:

- may not be aesthetically acceptable;
- requires purchase of land; and
- may reduce culvert capacity.

Review of Alternatives

Table 4 provides a summary of the alternative mitigation measures for Simpson Creek.

All three alternatives would require regular inspection of the bedload accumulation and of the structures for scour and abrasion. Regular inspections are necessary to check that the structure is capable of providing the intended risk reduction. Cost estimates for these inspections are not included.

The actual cost for average annual bedload removal could vary significantly due to the variation in runoff events. Due to the large volume of deposits to be removed a usage or nearby disposal site for the material should be investigated. Some of the material could be used for bank protection.

The deposition area above El. 538 m has the least capital cost because land does not have to be acquired. This is the recommended alternative due to the relatively low cost and low visual impact. The impact to fisheries would require assessment.

TABLE 4
SUMMARY OF SIMPSON CREEK ALTERNATIVES

ALTERNATIVE	ADVANTAGES	DISADVANTAGES	COST ESTIMATES	
			CAPITAL	AVERAGE ANNUAL EXCAVATION
Chute	• easy access for removal of deposits • stabilized channel for length of chute	• may not be aesthetically acceptable • vertical wall may be unsafe • may require land purchase • potential loss of fish habitat • bedload may cause chute abrasion	$101,000 for concrete $65,000 for half-culvert (land purchase excluded)	$9,000
Deposition Zone	• not visible from developed area • may slightly reduce peak flows • may incise downstream channel	• vegetation must be cleared for excavation • deposits removal would require periodic access in forested area by heavy equipment • may obstruct fish passage • may temporarily increase scour downstream	$84,000 at Nielsen Road $53,000 further upstream	$9,000
Widened Channel	• easy access for removal of deposits • very large discharge capacity • minimum fisheries impact	• may not be aesthetically acceptable • land purchase required • may reduce culvert capacity	$51,000 (land purchase excluded)	$9,000

8.2.2 Future Development Considerations

If extensive development ever occurs on the Simpson Creek fan, a setback dyke should be constructed to resist avulsions from the right bank of the creek. The dyke could be set back at least 30 m from the channel and would need large riprap to resist potentially high velocities of a breakout.

A bog which extends onto Lot 1 Plan 8739, Lot 1 Plan 8471, and Block B Plan 8075 should remain undeveloped. This area receives inflows from Simpson Creek plus numerous springs and attenuates the flow which enters the lower reaches of Simpson Creek. The area has a dense cover of vegetation which reduces flow velocity, removes suspended sediment, and limits erosion. The bog also provides a rich riparian and aquatic wildlife habitat.

A buffer zone of 30 m should be established between the natural boundary of the bog and any buildings. A dyke should be constructed on the outside edge of the buffer zone to protect development.

8.3 Biggs Creek

8.3.1 Mitigation of Existing Problems

A bedload deposition area already exists upstream of the Nielsen Road culvert. The area appears to be filled to capacity, but removal of the accumulated bedload would make it effective again in reducing downstream aggradation.

Lateral shifting of Biggs Creek downstream of the road is not endangering any residences and only grazing land has been temporarily flooded. Due to the low risk to life and property downstream, a capacity to retain the average annual bedload volume is adequate. Excavation of the deposition area would be mostly in the existing channel with excavation of the adjacent land only required to provide a more stable bank slope. The area should be excavated to the invert level of the old culvert, and the culvert should be cleared to provide a release capability at low flows. The excavation area would be approximately 20 m x 12 m and 1.5 m deep.

The inlet to the deposition area should be lined with large rocks from the excavation. Excavated material should also be used to protect the banks of the deposition area, in particular the left bank, which has been undercut and has slumped.

The deposition area should be monitored for bedload accumulation. Usually annual clearance should be sufficient, however, excavation of deposits may be necessary after extreme flow events. The small deposition area is meant to provide only a low degree of protection; therefore, with the existing state of development, the deposition should not be cleared out frequently merely to please landowners.

The creek will adjust over time to a condition of equilibrium downstream of the deposition area. Much of the sediment will be removed from the flow, thus the creek is expected to initially scour more than it will deposit until equilibrium is achieved. Most or all of the material deposited since the larger culvert was installed will probably scour and re-establish a well-defined channel along the road right-of-way. Trees should be preserved along the creek banks to provide stability.

If the road right-of-way is not needed by the Ministry of Transport and Highways, this land should be obtained by the Ministry of Environment rather than appending it to an adjacent lot. Government control of this strip of land would facilitate proper management of the creek.

The creek banks are unstable upstream of Nielsen Road. Trees should be planted along the banks to help stabilize the creek and reduce erosion.

The estimated cost of excavating the deposition area, protecting banks and planting trees is $6,000. Annual removal of deposition is estimated to be $3,500.

Future Development Considerations

If further development is going to be carried out, the banks upstream of Nielsen Road should be regraded to about 3H:1V and planted with grass, shrubs, and trees.

Any plans for development downstream of the road should include a reassessment of the size of the deposition area. If the potential flood losses increase downstream, the deposition area should be enlarged and/or excavation frequency increased to reduce the risk of excessive downstream aggradation. Development downstream should include dykes running parallel to the boundary with the existing road right-of-way. This would leave a wide floodway on the right-of-way and protect the developed land from inundation by Biggs Creek.

8.4 McKinnon Creek

8.4.1 Mitigation of Existing Problems

McKinnon Creek has a well defined channel at an 11% slope across Plans 6781, 5185, and 7407 upstream of Slack Road. The banks are stable along most of this reach, but more trees along the banks would be beneficial.

The Slack Road bridge has adequate hydraulic clearance; however, it should be checked regularly for debris to avoid blockage during high flows. The Ministry of Transport and Highways has a regular inspection schedule.

Downstream of Slack Road the channel slope varies from 6% to less than 4%. About 300 m of this reach of the creek was channelized two years ago; subsequently, the creek has started to return to a condition of equilibrium by developing a meander pattern. The banks have been undercut on alternate sides and material has deposited as small point bars at the inside of meanders. Meander development is a natural method of energy reduction; flow velocity, bedload, and erosion are reduced. The creek is unlikely to endanger existing residences as long as it is able to return to an equilibrium condition and debris is cleared from below the bridge.

The risk of flooding of the residence on Lot A of Plan 6982 would be reduced by blocking off the old channel that intersects McKinnon Creek downstream of the bridge. Although the invert of the creek is about 1 m below the old channel, an elevated tailwater level could flood it.

The estimated cost to place and compact fill in the old channel is $300.

8.4.2 Future Development Considerations

If the Lot A of Plan 6982 or Lot 2 of Plan 5234 are subdivided, a creek stabilization plan should be undertaken by the developer. The method of stabilization should be adapted to the creek morphology. Immediately downstream of Slack Road the creek has a relatively steep gradient and bank stability is a problem. Some 250 m downstream the gradient becomes more gentle and a wide floodplain is a problem.

The plan would entail stabilizing the natural bends of the creek where the channel is incised in the alluvium. Banks at point bars should be sloped as steep as 1.5H:1V at the outer portion of the meander. Vegetative and structural measures should be used to ensure stability of the banks, thus maintaining the naturally developed meander pattern. Only trees that are growing in the channel or are in immediate danger of falling in the channel should be removed.

Further downstream, on Plan 5234 in particular, the creek has large meanders and a wide floodplain. A creek stabilization plan for this area should include a 25 m band of vegetation outside the meanders on both sides of the creek and construction of a setback dyke to contain the floodplain of the creek. The dyke should be lined with riprap and trees should be planted on the crest.

8.5 Application of Municipal Act Section 734

Appendix II contains Section 734 of the Municipal Act. This study directly affects the application of Subsections 2 and 4.

Complete flood control and stabilization is not possible; consequently, there will always be flood and erosion risks on the alluvial fan. Mitigation measures can reduce the risk to existing development, and additional risk can be avoided by prohibiting future development.

If prohibition of new development is not an option, restrictions on development must be effected. These restrictions should include:

- no high risk buildings, such as schools, community centres, or emergency services, anywhere on the fan;
- no development in extreme and high hazard zones;
- in moderate hazard zones, site specific investigations should be carried out by a Professional Engineer to determine foundation and floodproofing requirements;
- in low hazard zones no site specific investigation would be required; and
- vegetation must not be removed from within 25 m of the natural boundary of a creek.

Residents of the alluvial fan should be aware of the risk involved and aware of the degree of protection that can be provided. Development of the fan should only be allowed to proceed if developers and occupants accept the natural hazards and are willing to share the initial and maintenance costs of risk reduction.

The hazard maps should be used by the building inspector to identify the need for specific assessments of construction suitability, as required under Subsection 2. The hazard zones are approximate boundaries and site specific hazards should be assessed where the site is near a creek or possible avulsion area.

Application for subdivision of any lot should include a detailed plan for stabilizing relevant creeks to protect against flood and avulsion damage. The plan must not adversely affect properties upstream or downstream and should be reviewed by an independent engineer at the developer's expense. Owners of the developed land and buildings should be responsible for the maintenance of the stabilization measures.

Clause 1.9.0 1(a) of Bulkley-Nechako Regional Bylaw No. 151 states that buildings must be at least 30 m from the natural boundary of a waterway. This bylaw must not be relaxed.

A 25 m width band of vegetation from the natural boundary of a creek should be maintained beside the natural boundary of a creek.

Basements should be prohibited in the entire study area.

9. RECOMMENDATIONS

Recommendations for existing flooding and erosion problems:

1. A deposition zone in Simpson Creek should be constructed on a relatively gentle slope about 130 m upstream of Nielsen Road.

2. A deposition zone should be excavated in Biggs Creek immediately upstream of Nielsen Road. Banks should be stabilized with riprap and trees planted.

3. McKinnon Creek should be allowed to achieve a condition of equilibrium. An old channel near Slack Road should be blocked.

4. The Biggs Creek road right-of-way should remain public property.

Recommendations for future development:

5. Natural morphology of creeks should be preserved or rehabilitated. A wide band of vegetation should be protected along the creek banks, natural creek geometry strengthened if necessary, and setback dykes constructed between the vegetation band and development.

6. If significant future development is contemplated, a comprehensive flood control plan should be implemented which would include construction of setback dykes along the entire lengths of the creeks.

7. Prospective residents must be advised of risks of living on an alluvial fan.

8. Hazard maps should be used by building inspectors. There should be no development allowed in extreme and high-hazard zones. In the moderate-hazard zones site specific investigations should be carried out by a Professional Engineer to determine foundation and floodproofing requirements.

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for Robert E. Baker, P.Eng.
Project Engineer

PROFESSIONAL ENGINEER
PROVINCE OF BRITISH COLUMBIA
C. D. SELLARS

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Project Manager

APPENDIX I

COST ESTIMATES

Cost Estimates of Simpson Creek Mitigation Alternatives

Alternative	Quantity	Units	Rate ($/unit)	Sum ($)
Alternative 1. Chute – Concrete				
Channel floor excavation	200	m3	6	1,200
Floor Granular Bed (local found)	140	m3	12	1,680
Floor Slab Concrete and Formwork	115	m3	200	23,000
Walls Concrete and Formwork	125	m3	400	50,000
Outlet Concrete and Formwork	6	m3	400	2,400
Rebar	15	tonne	1,000	15,000
Granular Backfill (local found)	150	m3	10	1,500
Property access crossing	1	item	6,000	6,000
Total				100,780
Alternative 1. Chute – Steel				
Channel floor excavation	200	m3	6	1,200
Floor Granular Bed (local found)	140	m3	12	1,680
Supply 3050 mm half culvert	140	m	325	45,500
Erect chute	140	m	60	8,400
Granular Backfill (local found)	150	m3	10	1,500
Property access crossing	1	item	6,000	6,000
Total				64,280
Alternative 2. Deposition Zone – d/s				
Clear and grub	3300	m2	1	3,300
Doze deposition area	13100	m3	2	26,200
Construct berm (use cut)	13100	m3	4	52,400
Riprap	175	m2	10	1,750
Total				83,650
Alternative 2. Deposition Zone – u/s				
Clear and grub	3000	m2	1	3,000
Doze deposition area	8100	m3	2	16,200
Construct berm (use cut)	8100	m3	4	32,400
Riprap	125	m2	10	1,250
Total				52,850
Alternative 3. Widened Channel				
Hoe existing channel	2000	m3	4	8,000
Disposal of excavated material	1800	m3	10	18,000
Riprap	1000	m2	10	10,000
Property access crossing	1	item	15,000	15,000
Total				51,000

APPENDIX II

MUNICIPAL ACT, SECTION 734

DIVISION (5) — BUILDING REGULATIONS

Building regulations

734. (1) The council may, for the health, safety and protection of persons and property, and subject to the *Health Act* and the *Fire Services Act* and their regulations, by bylaw

(a) regulate the construction, alteration, repair or demolition of buildings and structures;
(b) regulate the installation, alteration or repair of plumbing (including septic tanks and sewer connections), heating, air conditioning, electrical wiring and equipment, gas or oil piping and fittings, appliances and accessories of every nature and kind;
(c) establish areas to be known as fire limits and regulate the construction of buildings in specific area for precautions against fire, and discriminate and differentiate between areas in the character of the buildings permitted;
(d) regulate the seating arrangements and capacity of churches, theatres, halls and other places of public amusement or resort;
(e) require contractors, owners or other persons to obtain and hold a valid permit from the council, or the authorized official, before commencing and during the construction, installation, repair or alteration of gas or oil pipes and fittings, plumbing, heating, sewers, septic tanks, drains, electrical wiring, oil burners, tanks, pumps and similar works and buildings and structures of the kind, description or value described in the bylaw;
(f) prescribe conditions generally governing the issue and validity of permits, inspection of works, buildings and structures, and provide for the levying and collecting of permit fees and inspection charges;
(g) regulate or prohibit the moving of a building from one property to another in the municipality;
(h) require the fencing of private swimming pools or other pools, existing or prospective, according to specifications set out in the bylaw;
(i) regulate the construction and layout of trailer courts, mobile home parks and camping grounds and require that those courts, parks and grounds provide facilities specified in the bylaw;
(j) provide that no trailer or mobile home may be occupied as a residence or office unless its construction and facilities meet the standards specified in the bylaw; and
(k) require that, prior to occupancy of a building or part of it after construction, wrecking or alteration, or a change in class of occupancy of a building or part of it, an occupancy permit be obtained from the council or the authorized official. The permit may be withheld until the building or part of it complies with the health and safety requirements of the bylaws or of any statute.

(1.1) For the purposes of recovering the costs of administration and inspection, the council may impose rates or levels, or both, of permit fees and inspection charges referred to in subsection (1) (f) that may vary according to

(a) the cost,
(b) the type, and

(c) the size

of the work, building or structure in respect of which the permit is issued or the inspection made.

(2) Where a building inspector considers that construction would be on land that is subject to or is likely to be subject to flooding, mud flows, debris flows, debris torrents, erosion, land slip, rockfalls, subsidence or avalanche, he may require the owner of land to provide him with a report certified by a professional engineer with experience in geotechnical engineering that the land may be used safely for the use intended.

(2.1) For the purposes of subsection (2), "construction" means new construction of a building or structure, or the structural alteration of or addition to an existing building or structure, but does not include the repair of an existing building or structure.

(2.2) Subsection (2) does not apply where there are no bylaws under subsection (1) (a) in effect.

(3) Where a professional engineer with experience in geotechnical engineering determines that land may not be used safely for the use intended, the building inspector shall refuse to issue a building permit.

(4) Where a professional engineer with experience in geotechnical engineering determines and certifies that the land may be used safely for the use intended, subject to conditions contained in his report with respect to

- (a) the siting, structural design and maintenance of buildings, structures or works,
- (b) the maintenance or planting of vegetation,
- (c) the placement and maintenance of land fill, or
- (d) other conditions respecting the safe use of the land, buildings, structures or works,

a building inspector may issue a building permit on the condition that

- (e) the owner of the land covenants with the municipality or regional district to use the land only in the manner determined and certified by the engineer as enabling the safe use of the land for the use intended,
- (f) the covenant contains conditions respecting reimbursement by the covenantor for any expenses that may be incurred by the covenantee as a result of a breach of a covenant under paragraph (e), and
- (g) the covenant be registered under section 215 of the *Land Title Act*.

(5) [Repealed 1987-14-5.]

(6) Upon the application of an owner, a council or regional district board may, by resolution, direct its building inspector to issue a building permit but subject to the condition that a covenant referred to in subsection (4) be entered into and registered.

RS1960-255-714; 1964-33-68; 1968-33-173; 1978-22-10; *[amended 1981-11-36, to be proclaimed, amendment not included]*; 1985-79-2; 1987-14-5; 1989-32-8.

Refusal to issue building permit

734.1 A building inspector shall, where requested by an applicant, give written reasons for his refusal to issue a building permit.

1985-79-3.

Demolition or repair

735. (1) The council may by bylaw authorize

- (a) the demolition, removal or bringing up to a standard specified in the bylaw of a building, structure or thing, in whole or in part, that contravenes a bylaw or council believes is in an unsafe condition; or

APPENDIX III

REFERENCES

REFERENCES

Atmospheric Environment Service, Environment Canada, Precipitation and Temperature normals for Smithers, British Columbia.

Beaumont, Arthur, unpublished runoff equation for northern British Columbia.

Province of British Columbia, Aerial Photographs,
Flight line BC 1010: 1949
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Flight line BC 7748, 7779: 1975
Flight line BCC 765, 693: 1987

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Water Survey of Canada, Environment Canada, Streamflow data for gauge 08EE012, Simpson Creek at the Mouth, 1969-1990.

There are many forms of run-off formula and the one chosen here has been fitted to locally determined flows in streams for each locality. Flows from WSB for a few flows on main rivers and on many flows from smaller streams taken during highway surveys over the years have been utilized. The formula is of the type:

$$Q_{t_r} = k\ A^{b}\ t_r^{c}\ s^{-.23}\ T^{d}$$

"Beaumont Curves" for Regional Peak Flows from MoTH Prince George (Ed Cienciala

Where Q is flow in m^3/sec, A is drainage area in km^2, t_r is return period in years, s is percent of the storage in the basin, and T is the percent of the basin above timber-line.

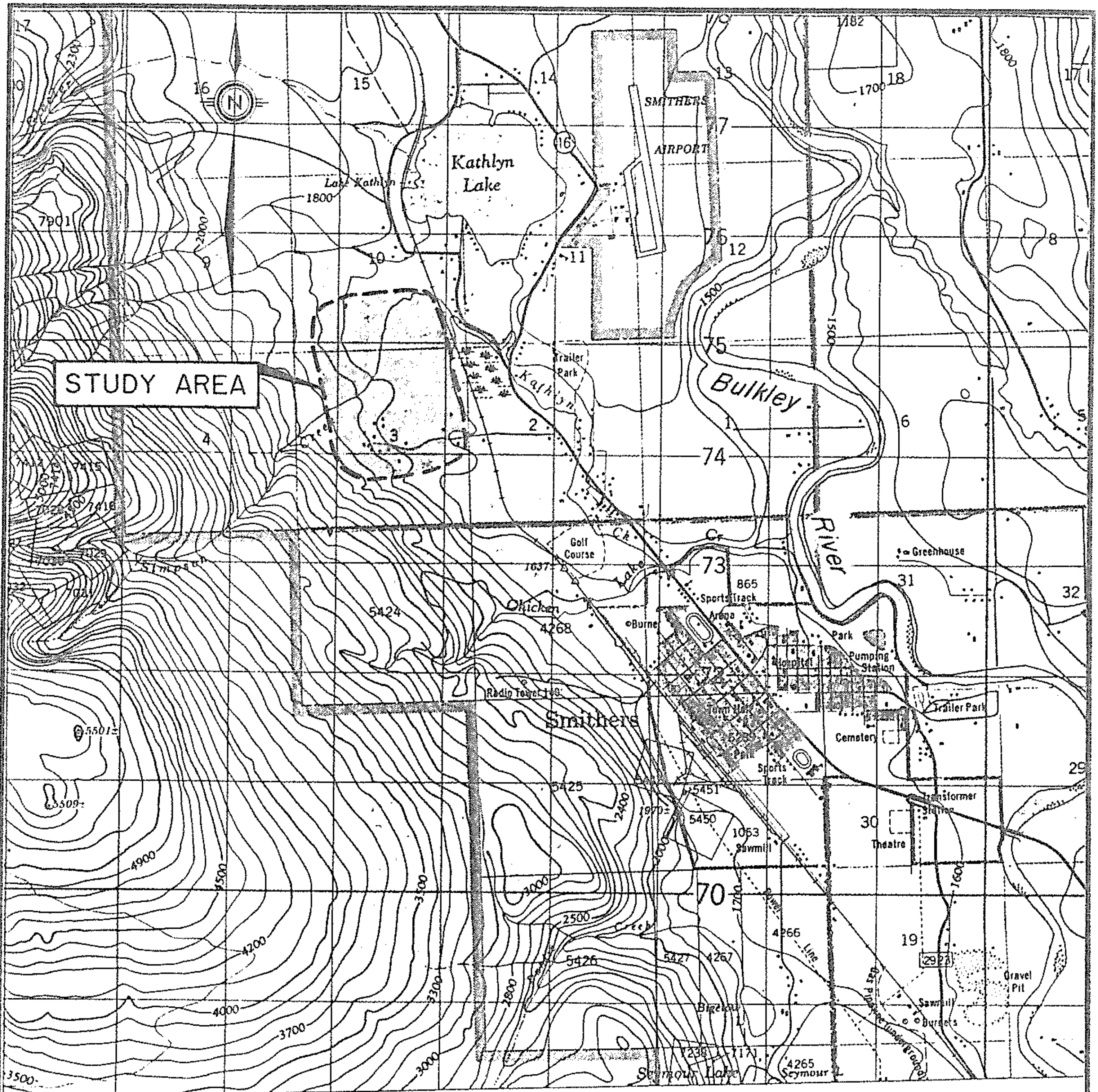
The constant term k and the various exponential terms are listed below for each locality where work has been done to evaluate them.

Locality	Description	Metric k	b	c	d	Imperial k
Prince George	All streams	.26	.8	.32	0	20
Quesnel, Barkerville	" "	.28	.75	.32	0	20
Quesnel Nazko	" "	.14	.75	.32	0	10
Bella Coola Heckman (Provisional)	" "	3.29	.7	.27	0	226
MacKenzie Pine Pass	Streams below 1100 m elev	.38	.7	.22	.55	26
MacKenzie Pine Pass	Streams above 1100 m elev	.57	.7	.22	.55	39
Dawson Cr Mt Lemoray	All streams	.62	.81	.32	0	47
Chetwynd Ft St John	All streams	.29	.81	.32	0	22
Chetwynd Sukunka	Basins under 13 km^2	.40	.75	.32	0	29
Chetwynd Sukunka	Basins over 13 km^2	.64	.75	.32	.55	46
Fort Nelson Maxhamish	All streams	.83	.75	.32	0	60
Vanderhoof Stuart L.	All streams	.22	.75	.32	0	16
Ft St James Germanson	Streams with no area above T.L.	.13	.8	.32	0	10
Ft St James Germanson	Streams with appreciable areas above Timber Line	.61	.8	.32	0	46

Locality	Description	Metric k	b	c	d	Imperial k
Queen Charlotte City to Skidegate	All streams	1.98	.8	.22	0	150
Prince Rupert & local	" "	1.98	.8	.22	0	150
Prince Rupert to 80 km E on Hwy 16	" "	3.57	.8	.22	0	270
Terrace W 60 km on Hwy 16 & to Kitimat	" "	3.17	.8	.22	0	240
Terrace Cedarvale	Streams under 15 km^2	1.52	.8	.26	0	115
Terrace Cedarvale	Streams over 15 km^2	1.98	.8	.26	0	150
Hazelton Smithers	Streams under 15	.40	.8	.26	0	30
Hazelton Smithers	Streams over 15	.80	.8	.26	0	60
Houston Burns L.	All streams	.42	.75	.32	0	30
Topley Babine	5 streams	.64	.75	.32	0	46
Kitwanga vanDyke	All streams	.58	.75	.32	0	42
vanDyke to Meziadin	All streams	.76	.75	.32	0	55
Meziadin	All streams	1.50	.75	.25	0	108
Meziadin Stewart	All streams	2.30	.75	.22	0	166
Alice Arm	All streams	3.57	.8	.22	0	270
Ningunsaw Burrage	All streams	1.00	.8	.32	0	76
Cassiar Dease Lake	Streams under 10 km^2	.40	.75	.32	0	29
Cassiar Dease Lake	between Dease River & Lake	1.53	.75	.32	0	110
Cassiar Dease Lake	All other streams	.72	.75	.32	0	52
Dease L. Telegraph	Streams below 1070 m elev	.10	.75	.32	0	7
Dease L. Telegraph	Streams over 1070 m elev	.31	.75	.32	.33	22
Goodhope L. Watson	Streams below 1070 m elev	.18	.75	.32	0	13
Goodhope L. Watson	Streams above	1.07	.75	.32	0	77

DRAWINGS

A-1001	-	KEY PLAN
A-1002	-	CADASTRAL MAP
D-1003	-	HAZARD MAP
D-1004	-	CADASTRAL MAP AND HAZARD ZONES
D-1005	-	MITIGATION MEASURE ALTERNATIVES



SCALE 1 : 50 000

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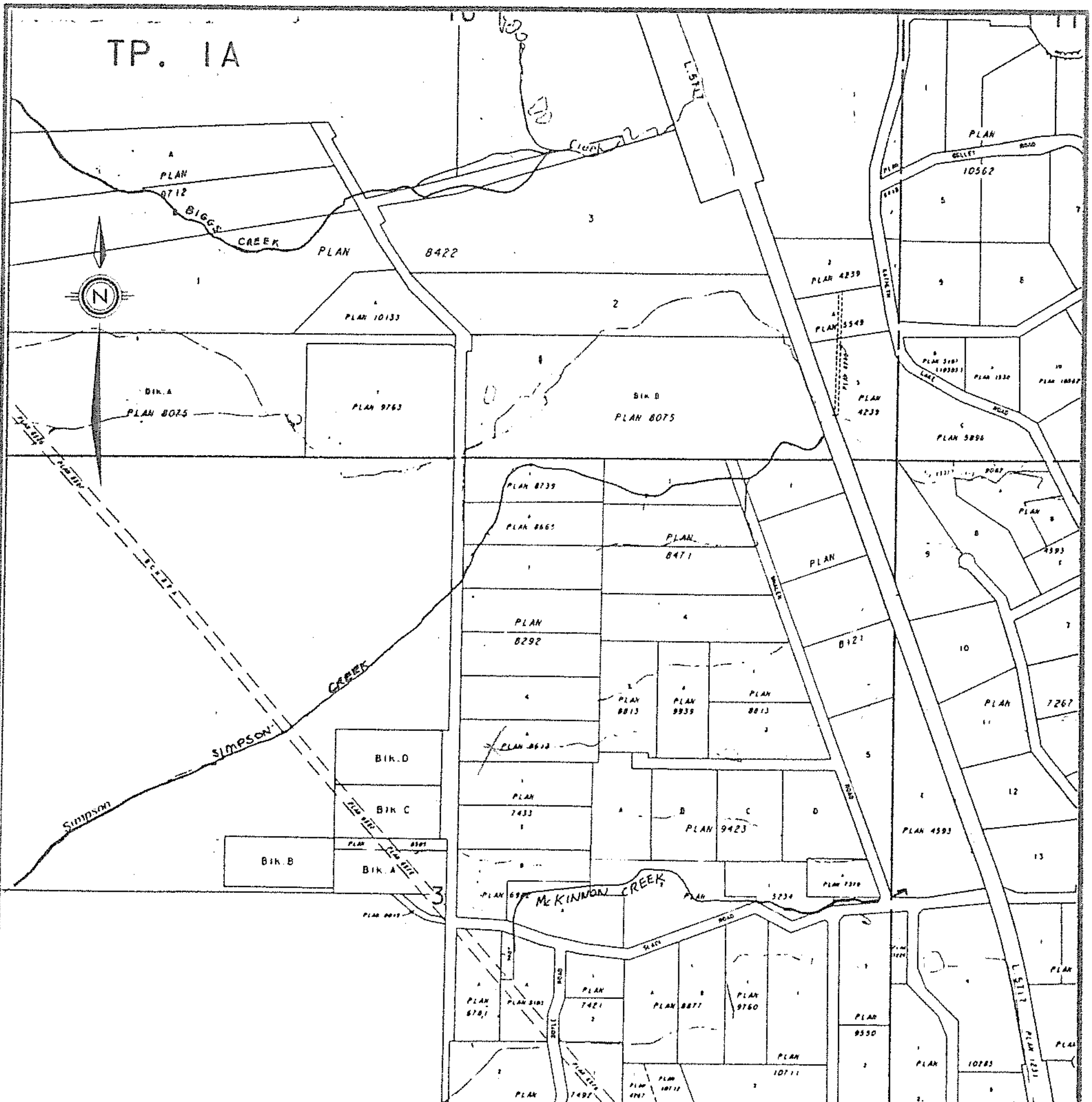
PROJECT	ALLUVIAL FAN STUDY
TITLE	KEY PLAN

CLIENT:	DATE OF ISSUE	PROJECT No	DWG. No	REV.
B.C. MINISTRY OF ENVIRONMENT SKEENA REGION	MAR. 20, 1991 APPROVED	PB 5543 01	A-1001	



SCALE 1 : 10 000

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PROJECT: ALLUVIAL FAN STUDY

TITLE: CADASTRAL MAP

CLIENT: B.C. MINISTRY OF ENVIRONMENT SKEENA REGION

DATE OF ISSUE	PROJECT No	DWG No	REV.
MAR. 20, 1991	PB 5543 01	A-1002	

APPROVED